SITUATION AWARENESS IN AIRWAY FACILITIES: EFFECTS OF EXPERTISE IN THE TRANSITION TO OPERATIONS CONTROL CENTERS

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ABSTRACT

The Federal Aviation Administration plans to consolidate the present Maintenance Control Centers (MCCs) into three Operations Control Centers (OCCs). This consolidation should increase efficiency and service by centralizing operations and standardizing procedures. We examined the likely effects of consolidation on specialists' situation awareness (SA) in the context of two basic plans. First, the Area-Specialist Plan maintains OCC specialists' responsibility for the same geographical areas they had in the MCC, while continuing to monitor and control multiple technical systems. Second, the Technical-Specialist Plan divides the responsibility of operations for one-third of the country between specialists in different technical areas. We discuss the tradeoffs for each plan.

INTRODUCTION

Researchers have studied SA in many environments including fighter pilots (Carretta, Perry, & Ree, 1996; Endsely & Bolstad, 1994), Certified Professional Controllers (CPCs) (Durso, Truitt, Hackworth, Crutchfield, & Manning, 1998; Hopkin, 1994), automobile drivers (Chukwurah, Durso, & Truitt, 1999; Gugerty, 1997), anesthesiologists (Gaba, Howard, & Small, 1995; Small, 1995), and chess players (Durso, Truitt, Hackworth, Crutchfield, Ohrt, Nikolic, Moertl, & Manning, 1995). Pilots, CPCs, and others involved in dynamic environments have an intuitive sense of what it means to have good SA. For controllers, SA is simply "having the picture" or "not going down the tubes." More formal definitions of SA exist in the scientific literature (Durso & Gronlund, 1999; Endsley, 1988; Fracker, 1989; Mogford, 1994; Pew, 1994; Tolk & Keether, 1982), and each differs in fine distinctions. However, all tend to capture the same basic principle, that is, to have good SA is to be aware of the present state of events and to be able to predict and anticipate future events in a dynamic environment.

A lower and upper bound determines the potential of one's SA (Durso & Gronlund, 1999). SA is limited at the lower bound by the divided attention capacity of the individual. In other words, the amount of attention an individual gives to a task places a limit on SA. In addition, the individual must be able to acquire information from the environment and understand the meaning and implications of that information. To have adequate SA, one must have the prerequisite expertise regarding the system of concern so that the correct information may be extracted from the environment and implications can be comprehended. The amount of attention given to a task determines how well information is acquired, updated, and understood.

At the upper bound, the predictability of the dynamic system at hand determines potential SA. If the behavior of a system were completely random, then it would be impossible to predict and anticipate any future states of the system. On the other hand, in a system that has some predictability, one can use existing knowledge and expertise to anticipate future states.

REPLACING MCCS WITH OCCS

The goal of consolidating MCCs into OCCs is to centralize and standardize AF activities in order to improve service to users and customers of the National Airspace System (NAS). The consolidation is meant to concentrate expertise in one location (an OCC) thereby increasing organizational efficiency. There are two hypothetical plans in which the consolidation may occur.

The first plan proposes OCCs staffed by specialists who are experts in a particular technical field or system (FAA, 1997). Hereafter, we refer to this plan as the "Technical-Specialist Plan." A second approach would build upon current operations by having OCCs staffed by specialists who are experts in a particular geographical area. This second plan would basically maintain the status quo and we refer to it hereafter as the "Area-Specialist Plan." This document compares and evaluates both plans in terms of their likely effects on specialists' SA and performance in OCCs. The tradeoff between area-specific knowledge and technical knowledge must be carefully considered.

The Technical-Specialist Plan

Under the Technical-Specialist Plan, replacement of MCCs with OCCs will result in two major changes to the task of the current MCC specialist. The first change involves an increase in the size of the geographical area that will concern the specialist. The second change concerns a shift in responsibility from one or two specialists who act as “generalists” (they monitor and maintain various facilities) to a larger team of specialists, each of whom will concentrate primarily on a single technical facet of the facilities that they monitor and maintain.

Increased Geographical Area of Responsibility

Currently, 42 MCCs are responsible for monitoring and coordinating AF maintenance within the U.S. Each MCC handles a relatively small geographical area. With the advent of OCCs, there will only be three OCCs with each covering a geographical area roughly equivalent to one-third of the U.S. Being responsible for a larger geographical area may affect an OCC specialist’s SA. The specialist’s SA may suffer initially under the Technical-Specialist Plan because the area-specific knowledge gained in the MCC will apply only to a small portion of the geographical area in an OCC. In order to have sufficient SA, the specialist must have adequate area-specific knowledge of the environment and systems in the domain. For example, the specialist must know about various environmental, terrain, and historical reliability factors that may impact the current and future status of any particular site. Therefore, it may be difficult to predict and anticipate the future state of systems without area-specific knowledge.

One proposed solution to compensate for the lack of area-specific knowledge is to establish databases containing the knowledge possessed by current MCC specialists (AOP ODT, 1999). However, even if complete databases did exist, information would not be readily accessible to the OCC specialist without a thorough and time-consuming search. Having to search a database to be able to predict effects of factors such as weather does not only imply a limit on the specialist’s SA for future events but also would increase workload and lengthen the time it took to respond to current or anticipated conditions. If specialists used a database to acquire knowledge during an unplanned outage caused by area-specific factors, they would simply be reacting to the outage. Databases would help specialists become more proactive only after they have had time to study and acquire the knowledge contained therein.

A second remedy for diminished area-specific knowledge is to detail OCC specialists to MCC facilities prior to opening OCCs (AOP ODT, 1999). This solution would give the OCC specialists some experience in other geographical areas. However, it may take considerable time before OCC specialists would gain the level of knowledge needed to operate efficiently. A presentation by McMannis Associates (1997) states that MCC specialists require an average of 2 years of on-the-job training (OJT) in addition to formal training before they become proficient at their job.

A third solution to help OCC specialists gain area-specific knowledge is to conduct OJT on site. By selecting specialists from a variety of MCCs to staff the OCCs, area-specific knowledge could be shared among the OCC staff members. However, such training requires OCC specialists to have time available to share knowledge with each other. It is not apparent that much time would be available for OJT considering that about 16 to 20 specialists would be responsible for the monitoring and maintenance activities for an entire one-third of the country.

Although lack of area-specific knowledge will eventually be remedied over time, in the interim, specialists are likely to have difficulty maintaining SA for events in which area-specific knowledge is needed to predict those events. The inability to anticipate problems may result in more frequent unplanned outages than previously experienced in the MCCs.

A benefit of the Technical-Specialist Plan is that once an outage occurred, specialists would have the expertise to rectify the outage. This expertise may allow a more efficient response to an outage. Specialists who are technical experts would be able to remotely repair many facilities. These specialists would also have more knowledge about the type of equipment they are monitoring and may be able to notice and correct anomalies before an outage occurs.

The specialists’ inability to predict events based on area-specific knowledge may be offset by the ability to predict events based on technical knowledge. If the tradeoff favors area-specific knowledge, some decrement in NAS quality should be expected until OCC specialists are able to gain adequate area-specific knowledge to be able to predict situations that may result in outages. However, if the tradeoff favors technical knowledge, then little or no decrement in NAS quality should be expected as a result of better SA for both present and future events. In fact, it is possible that fewer unplanned outages would occur under the Technical-Specialist Plan because specialists would be more likely to notice and correct anomalies due to their superior technical knowledge.

Redistribution of Responsibilities

Currently, MCC specialists act as generalists in that they monitor, maintain, and track activities regarding numerous technical systems. In contrast, under the Technical-Specialist Plan, specialists in each OCC would divide responsibilities between approximately 16 specialists in five or six different technical areas. Specialists would be experts in their respective technical area. MCC specialists are already experts in at least one technical field, so the impact of transitioning from a generalist to a specialist should be minimal.

OCC specialists may experience a positive benefit due to the redistribution of responsibilities. Technical specialists would be more able to notice and deal with anomalies for systems they were monitoring. Because each specialist would be an expert in their technical field, they would have more knowledge and experience to recognize conditions that may lead to unplanned outages. Additionally, there may be fewer unplanned outages because attention could be dedicated primarily to one particular technical system. Technical specialists may have better SA for both the present and future situation and would be better able to prevent unplanned outages. Once an outage did occur, the time it took to repair an outage should be shortened because the technical specialist would have a better understanding of the affected system.

The redistribution of responsibilities in the OCC may improve specialists' SA for both present and future events regarding a single technical system, but specialists may have lower SA for other related systems. Rather than SA residing with one or two specialists as in an MCC, SA in an OCC may be distributed across a relatively large team of 16 to 20 specialists under the Technical-Specialist Plan. Although it is not likely that all members of the OCC team would need to share all available information, there will have to be a certain degree of shared, or group, SA.

A final possible effect of redistributing responsibilities under the Technical-Specialist Plan is the potential for a higher level of workload. Although OCC specialists may be able to predict and deal more efficiently with outages that did not depend on area-specific knowledge, it is possible that their technical expertise would not be sufficient to offset the increase in workload resulting from a higher specialist-to-facility ratio. A linear increase in workload is likely to translate into exponential decreases in SA at some point (K. Grayson, personal communication, August 26, 1999). Therefore, if there is a higher facility-to-specialist ratio, it should be ensured that the specialists' technical expertise would be able to offset any increases in workload.

There is no evidence at this time that the benefit of area-specific knowledge outweighs the benefit of technical expertise, but there are tradeoffs that would occur. It is an empirical question whether technical expertise would overcome a possible increase in workload due to 1) higher specialist-to-facility ratio than MCCs, and 2) the potential for an increase in the number of unplanned outages due to lack of area-specific knowledge. Finally, under the Technical-Specialist Plan, the redistribution of responsibilities requires that the issue of maintaining adequate group SA must be considered in the design and implementation of OCCs.

The Area-Specialist Plan

The Area-Specialist Plan is an alternative to the Technical-Specialist Plan. This plan of having each OCC specialist be responsible for only a small portion of the total area within an OCC was mentioned during previous interviews with subject matter experts (AOP ODT, 1999) and is essentially equivalent to maintaining current operations. This plan would consolidate MCCs within the geographical boundary of an OCC into a single location. The consolidation would allow the assignment of MCC specialists to future OCCs while still maintaining responsibility for the same geographical location.

No decrements in specialists' SA would be expected because they would already possess the area-specific knowledge needed to be proactive in preventing unplanned outages. Therefore, the rate of unplanned outages due to area-specific factors should not increase. However, specialists would not be experts in all the systems they were monitoring. This lack of expertise would make them less likely to understand the implications of anomalous parameter values, and they may not be able to utilize remote control capabilities. Specialists may have lower SA for both present and future events that depended on technical expertise. However, because there would be essentially the same number of specialists responsible for the facilities as in MCCs and specialists would be consolidated in one location, it is likely that all areas of technical expertise would be represented.

The Area-Specialist Plan does not call for a substantial reduction in workforce, so it is likely that workload would remain manageable. SA for all systems within a particular geographical area would reside with a few specialists rather than distributed across numerous technical experts. The issue of maintaining group SA would be important only to the extent that specialists from various geographical areas need to share information with one another.

Comparison and Testing of the Plans

There will be tradeoffs regardless of which plan is implemented. The Area-Specialist Plan favors area-specific knowledge over technical knowledge while keeping SA in the purview of several individuals who must distribute their attention over a number of different systems. The Technical-Specialist Plan focuses attention on a particular system and distributes SA across a larger team of individuals. These two alternatives present very different views of how best to implement OCCs. It would be difficult to test all hypotheses in just a few experiments. Therefore, it is proposed that the tradeoffs that appear to pose the greatest risk to the implementation and performance of future OCCs be examined by empirical methods.

MEASUREMENT OF SA

Given the options that are available for the implementation of OCCs, it would be worthwhile to compare specialists' SA for different alternatives. Many different methodologies to measure SA currently exist including subjective and objective measures. Furthermore, participants and observers can provide measures of SA either on-line or off-line. Measures previously used for the assessment of SA include psychophysiological measures such as eye movements (e.g., Moray & Rotenberg, 1989; Wierwille & Eggemeier, 1993), electroencephalograms and heart rate (e.g., Wilson, 1995), verbal protocol analysis (e.g., Ohnemus & Biers, 1993; Sullivan & Blackman, 1991), post-hoc techniques (e.g., Durso, Truitt et al., 1998; Rodgers, Mogford, & Mogford, 1995; Strauch, 1995), retrospective recall (e.g., Kibbe, 1988), supervisory and peer ratings (e.g., Bell & Waag, 1995), subjective rating techniques (e.g., Taylor, 1990; Vidulich & Hughes, 1991), memory probes (e.g., Endsley, 1988), and on-line queries (e.g., Durso et al., 1995). For a current review of SA and methodologies used to assess SA, see Durso and Gronlund (1999).

Objective Measures of SA

Durso et al. (1995) have developed an objective measure of SA that overcomes the problems of relying on memory, interruptions, and the frequency with which meaningful data can be collected. The Situation Present Assessment Method (SPAM) is an on-line query technique that allows the assessment of a participant's SA without interrupting the simulation or real-world activity. Initially developed with chess players, researchers have used SPAM successfully with CPCs in simulations (Durso, Hackworth et al., 1998; Willems & Truitt, 1999), and automobile drivers in real driving situations (Chukwurah, Durso, & Truitt, 1999).

Measurement of SA in AF

The best measures of SA in the AF environment are yet to be determined. However, it is reasonable to expect that both subjective and objective measures of SA would be appropriate. Subjective measures of SA will be useful because specialists will likely notice large changes in their SA that may be induced by certain conditions such as lack of area-specific knowledge. Objective measures of SA should also be used to support the subjective ratings. Researchers may employ an implicit measure of performance to assess how quickly specialists noticed an outage or how quickly specialists took the proper action to prevent or resolve an outage. Additionally, an on-line query method such as SPAM could be used to assess how aware specialists are of information relevant to the present and future state of the system. An ability to predict the future may be especially important because designers of the OCCs would like specialists to be more proactive. The SPAM measure of SA could be implemented in a realistic way so as not to interrupt the simulation to any large extent.

CONCLUSIONS AND RECOMMENDATIONS

SA is relevant for the MCC specialists in that they must maintain an awareness of the current status of the NAS and be able to predict future status. Specialists maintain SA by using both area-specific and technical knowledge. Specialists in the MCC are able to anticipate future status in part because they possess a relatively high level of area-specific knowledge about the facilities of concern. However, current MCC specialists often lack the technical expertise that is required to recognize anomalous parameter readings and repair a system once an unplanned outage has occurred.

OCC specialists under the currently used Area-Specialist Plan would remain responsible for numerous operations concerning a small geographical area. This plan does not focus technical expertise in a particular facet of OCC operations, but it does eliminate the need for additional training and immediate construction of databases while leaving area-specific knowledge intact. However, maintaining the status quo is advantageous for SA only to the extent that area-specific knowledge is important for specialists to be able to anticipate and counteract outages before they occur. Specialists may have a lower level of SA for present and future events as compared to specialists in the Technical-Specialist Plan to the extent that SA relies on technical expertise.

Area specialists in current MCCs are not able to focus their attention on a particular system. In addition, the parameters of the systems being monitored do not provide the same depth of information and meaning as they would to a specialist with technical expertise. The Area-Specialist Plan should ensure that workload will not be excessive during the initial phase of OCCs and eliminates, to some extent, the necessity to address issues regarding distributed group SA. Group SA will be important though to the extent that specialists from different geographical areas need to interact with one another.

The implementation of OCCs under the Technical-Specialist Plan will eliminate most of the area-specific knowledge currently possessed by MCC specialists because specialists will be responsible for a much larger and unfamiliar geographical area. Although area-specific knowledge may reside in a database, such knowledge will not be readily available for use during an outage. Databases would eventually help specialists become more proactive once they were able to gain experience with the databases and acquire the knowledge contained therein. Until OCC specialists gain area-specific knowledge or until an artificial intelligence mechanism is in place, they will largely have to react to outages that have already occurred due to area-specific factors such as weather or terrain. In other words, it is expected that OCC specialists may have very poor SA for future events that rely on area-specific knowledge to be detected. This problem may be compounded by the fact that SA will have to be distributed among a team of specialists. Workload may also increase under the Technical-Specialist Plan because it is expected that fewer specialists will be responsible for the same number of facilities.

On the other hand, the Technical-Specialist Plan may offset any increases in workload and/or number of unplanned outages because of specialist technical expertise. Workload may be offset because specialists will be technical experts in monitoring, preventing, solving, and rectifying unplanned outages. Technical experts should have better SA for the present and future events that are not dependent on area-specific knowledge. Furthermore, technical specialists could focus their attention primarily on one facet of the monitoring and maintenance responsibilities and, thereby, enhance SA for the system being monitored.

Empirical investigations of the hypothesized effects should be conducted. Because of the complexity of each plan, a careful study of the effects with the greatest potential to impact the OCC should be given priority under time constraints. Results from these investigations can then be used to help further inform decision makers as to which plan would be most beneficial for SA and the implementation of OCCs.

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